Annex 8: LNG and gas quality and measurement manual

1. LNG and gas quantity, quality and pressure specifications

1.1. Quality specifications for the LNG at the Delivery Point

The LNG quality specifications are as follows (**):

PROPERTIES		**SPECIFICATION**	**MEASUREMENT UNIT**
Wobbe Index	Minimum	47,31	MJ/Sm³
	Maximum	53,00	MJ/Sm³
GCV	Minimum	(*)	MJ/Sm³
	Maximum	(*)	MJ/Sm³
H2S + COS (as sulphides)	Maximum	≤ 5	mg/Sm3
Mercaptans (as sulphides)	Maximum	≤ 6	mg/Sm3
Total sulphur (as sulphides)	Maximum	≤ 20	mg/Sm3
Mercury (Hg)	Maximum	10	Nano g/Sm³
Hydrocarbon dew point (cricondentherm)	Maximum	≤ 0	°C (1-70bara)
Water (H2O)	Maximum	0,1	ppm (vol)
Oxygen (O2)	Maximum	0.6	% mol
Carbon Dioxide (CO2)	Maximum	2.5	% mol
Solids		No deposits on 60 mesh filters	
LNG density	Minimum	420	kg/m³
	Maximum	470	kg/m³

The reference standards for GCV and Wobbe Index are: ISO 6976:1995 calorific values (reference combustion temperature: +15°C, standard cubic metres +15°@ 1.01325 bara). It is understood that the quantity and quality measurements recorded at the time of unloading will be communicated and shared in accordance with the procedures and reference standards referred to in paragraphs 2.7 and 2.8.

(*): if the Wobbe Index is within the specifications, the GCV and the individual components are acceptable.

(**): Please note that 1 kJ/Sm³$_{15°/15°}$ = 0.0002775 kWh/ Sm³$_{25°/15°}$ and 1 kWh/ Sm³$_{25°/15°}$ = 3603.6 kJ/Sm³$_{15°/15°}$. These conversion factors shall be used also for unloading certificates and reports as per paragraph 2.8.

1.2. Impurities

The Unloaded LNG must not contain solids, contaminants or extraneous material that may interfere with its saleability or cause damage or interfere with the Terminal's operations.

If the total sulphur content is less than five (5) mg/Sm³, it will not be necessary to analyse the sample of hydrogen sulphide and mercaptans sulphide.

To avoid any occlusion or erosion of the equipment, the Unloaded LNG must not contain any concentrations of fluid components (e.g. aromatics, C6H6, CO2, CH3OH, etc.) that exceed fifty percent (50%) of the solubility limit for that particular component within an operating pressure range of 0 to 100 bar and within an operating temperature range of -162 to +50°C. C6H6: max. 1 ppm, CH3OH: max. 0.5 ppm.

The LNG quality specifications are subject to modification at any time as required to conform with the Gas quality specifications.

1.3. Gas Quality Specifications at the Redelivery Point

The qualitative characteristics of the gas injected into the National Transmission System are those resulting from the analyses performed at the Terminal, based on the quality monitoring methods, procedures and instruments used at the Terminal itself. The regasified LNG injected into National Transmission System will comply with the quality and pressure specifications for gas injection required by SRG in accordance with the provisions of the Grid Code – provided that the LNG Unloaded and delivered by the User complies with the specifications at the Delivery Point.

The Operating Company, which has the transportation capacity at the Redelivery Point pursuant to article 8, paragraph 1, of Resolution no.137/02, complies with the quality specifications envisaged by the Grid Code pursuant to article 8, paragraph 1, of Annex A to Resolution no.185/05.

2. Measurement, Sampling and Analyses of LNG and Gas

2.1. Definitions

The relevant Standards and procedures such as GPA, API, ISO, EN or ASTM are updated in line with the latest revisions.

2.2. LNG Measurement Tests and Methods: Tank Gauge Tables

Prior to using any LNG Carrier, the User shall: (a) where the LNG Carrier's tanks and volume measuring devices have never be calibrated, arrange for a qualified classification entity selected by the User and the Operating Company of the Terminal to calibrate each tank and volume measuring device for volume against level, or (b) where the LNG Carrier's tanks and volume measuring devices have been previously calibrated, provide the Operating Company with proof of such calibration prepared by a qualified classification entity and, if necessary, arrange for the recalibration of all the tanks and volume measuring devices by a qualified classification entity selected by the User and the Operating Company.

2.2.1. Preparation of the Tank Gauge Tables

The LNG Carrier's tank tables must be verified by a qualified inspector. Such tables must include the calibration tables, trim and list correction tables, volume corrections to tank temperature and other corrections, where necessary. The calibration tables must be verified by a qualified classification body and made available for consultation by the Maritime Authorities. The LNG Carrier must present its inspection certificates showing the last inspection.

2.2.2. Accuracy of the Tank Gauge Tables

The tank gauge tables prepared in accordance with section 2.1.1 must indicate volumes in cubic metres expressed to the thousandth, with the depth of the tank expressed in metres to the thousandth.

2.2.3. Certification of Tank Calibration

The Operating Company is entitled to be present at the calibration of the tanks envisaged by section 2.1.1. The User shall give the Operating Company reasonable prior notice of the tank calibration.

2.2.4. Recalibration of the LNG Tanks in the case of Deformation, Reinforcement or Modification

In the event that one of the LNG tanks of an LNG Carrier becomes deformed or is reinforced or modified to such an extent as to call into question the validity of the gauge table envisaged by section 2.1.1 above, the user shall arrange for their recalibration in accordance with the procedure set forth in sections 2.1.1 and 2.1.2 above during a period when such LNG Carrier is out of service for inspection and/or repairs. The user shall bear the costs of the recalibration unless the latter was carried out at the Operating Company's request and there were no inaccuracies in the tank gauge tables, in which case the Operating Company shall bear the recalibration costs.

Apart from the cases envisaged by this section 2.1.4, no recalibration of any LNG tank of any LNG Carrier is required.

2.3. LNG Measurement Tests and Methods: Selection of Measurement Devices

2.3.1. Liquid-Level Measurement Devices

ISO 10976 specifies that at least two independent devices for measuring the liquid level must be available for each cargo tank. The primary and secondary measuring systems must be independent, so that if one fails the other will not be affected.

ISO 10976 defines the measuring precision of both primary and secondary devices: +/- 5mm (some systems are unable to meet this verification tolerance, in which case a verification tolerance of +/- 7.5 mm may be applied).

The measurement devices must be certified for off-shore use.

2.3.2. Temperature Gauges

ISO 10976 specifies that there should be a minimum of five temperature sensors in the tank and at least one of them must be located above the maximum fill height so as to remain in the vapour space. Each temperature sensor shall be supported by a secondary sensor mounted adjacent to the primary sensor. The ATT system shall read and provide individual temperatures for both liquid and vapour space and allow their averages to be determined. In any case, LNG Carriers equipped with fewer temperature sensors (but still in accordance with the IGC Code requirements) may also be considered.

Two sensors including spares shall be installed - one on the tank bottom and the other at the top - to ensure constant measurement of the temperatures of the liquid and vapour, respectively. The remaining sensors shall be installed at an equal distance from the bottom and the top of the tank. All of the sensors shall be installed in such a way as to ensure that they are not affected by the operation of the spray pumps.

ISO 10976 specifies that the accuracy of the temperature measuring devices must be as follows:

Temp. Range, °C	Range,
-165 to -145	+/-0.2

2.3.3. Pressure Gauges

Each tank of each LNG Carrier must have a single pressure gauge.

ISO 10976 specifies that the accuracy of the pressure gauges must be +/- 0.3 kPa

2.4. LNG Measuring Tests and Methods: Measuring Procedures

2.4.1. General

ISO 10976 defines the measurement of the cargo on board LNG Carriers.

Before any measurement can take place, the gas to boilers line must be isolated, spray pumps and boil-off gas compressors switched off, loading arms connected and LNG Carrier's manifold valves closed. If gas combustion is permitted, then the gas flow meter must be recorded at the same time as OCT and CCT are performed. The Master of the LNG Carrier shall ensure that its monitoring devices operate properly and demonstrate that they have been calibrated by a qualified body. Calibration certifications must be available on request.

CCT measurement shall take place after unloading is completed, with transfer pumps switched off and allowing sufficient time for the liquid level to stabilise.

In volumetric terms, the condition of the loading arms and the unloading line should be the same for OCT and for CCT, whether empty or full. Any other device that may be used should be in the same condition for OCT and CCT.

The User, the Operating Company or their representatives are entitled to be present during each measurement, but the absence of a representative will not prevent the measurement from taking place

2.4.2. Liquid Level

The liquid level in each LNG tank of each LNG Carrier is measured to the nearest millimetre by using the primary liquid level measuring device referred to in Section 2.2.1 above.

The Five (5) readings shall be made in as rapid succession as possible. The arithmetic average of the readings shall be deemed to be the liquid level. The supplier of the measuring device must ensure that the CTMS is able to offset the dynamic movement while the LNG Carrier is moored at the Terminal. The internal level sampling rate of the CTMS shall be sufficient to enable adequate processing, providing the aforementioned readings at intervals of 15 seconds so as to be stable within CTMS accuracy limits. Such information must be included as part of the LNG Carrier calibration already approved by a qualified inspector. Any variation in the prescribed number of readings that may be required to offset the dynamic movement of the LNG Carrier while moored at the Terminal must be provided by the supplier of the measuring equipment. Such information must be included as part of the LNG Carrier calibration tables already approved by a qualified inspector.

Such arithmetic average shall be calculated to the nearest tenth of a millimetre (0.1) and shall be rounded off to the nearest millimetre.

Such liquid level measuring device must be used for both the initial and final measurements during unloading at the Delivery Point. If the main measuring device is inoperative when Unloading commences, necessitating use of the auxiliary measuring device, the auxiliary measuring device shall be used at the end of the Unloading, even if the main measuring device has subsequently become available. The trim and list of the LNG Carrier must remain the same while such measurements are performed.

The liquid level in each LNG tank shall be recorded or printed

2.4.3. Temperature

At the same time the liquid level is measured, temperature shall be measured to the nearest tenth of a degree Celsius (0.1°C) by using the temperature measuring devices referred to in Section 2.2.2 above.

In order to determine the temperature of liquid and vapour in the tanks of the LNG Carrier, one (1) reading is taken with each primary temperature measuring device in each LNG tank. The arithmetic average of such readings with respect to the vapour and liquid in all LNG tanks shall be deemed to be the final temperature of the vapour and liquid.

Such arithmetic average must be calculated to the nearest hundredth of a degree Celsius (0.01°C) and must be rounded off to the nearest tenth of a degree Celsius (0.1°C).

The temperatures in each LNG tank shall be recorded or printed.

2.4.4. Pressure

At the same time the liquid level is measured, the absolute pressure in each LNG tank must be measured to the nearest millibar by using the pressure measuring device referred to in Section 2.2.3 above.

The absolute pressure in the LNG tanks of each LNG Carrier must be determined by taking one (1) reading of the pressure measuring device in each LNG tank, and then considering the arithmetic average of all such readings.

Such arithmetic average must be calculated to one tenth (0.1) of a millibar and rounded to the nearest one (1) mbar.

In the event that an LNG Carrier uses units other than millibars, the Operating Company and the User may convert to millibars by using internationally recognised conversion factors.

The pressure in each LNG tank shall be recorded or printed.

2.4.5. Procedures in the case of Measuring Device Failure

If it is no longer possible to perform the measurements referred to in sections 2.3.1, 2.3.2, 2.3.3 and 2.3.4 due to a failure of the measuring devices, alternative measuring procedures will be established by mutual agreement b the Operating Company and the user having consulted an independent inspector.

2.4.6. Determination of the Volume of Unloaded LNG

The list and trim of the LNG Carrier must be measured at the same time as the liquid level and temperature of the LNG in each LNG tank are measured. ISO 10976 specifies that the tolerance permitted on trim readings is +/- 50 mm. The tolerance permitted on list measurement is +/- 0.05 Degrees. The LNG Carrier's LNG cargo transfer pipes must contain hydrocarbons in the same state during the final measurement as at the initial measurement. Vapour lines connected to the manifold must remain open to ensure that the vapour pressure in all LNG tanks is equalized. Such measurements shall be made immediately before any Cargo operation commences and immediately after Unloading is completed and after the loading arms and vessel lines have been drained. The volume of LNG, stated in cubic meters to the nearest one thousandth of a cubic metre (0.001), shall be determined by using the tank gauge tables referred to in Section 2.1 and by applying the volume corrections set forth therein.

The volume of Unloaded LNG shall be determined by deducting the total volume of LNG in all the tanks immediately after unloading is completed from the total volume in all tanks immediately before unloading commences. This volume in cubic metres of Unloaded LNG shall be rounded to the nearest one thousandth of a cubic metre (0.001).

Upon completion of the CCT measurements, all measurements recorded from the CTMS shall be printed to form three certificates, as follows:

Opening Transfer Measurement Certificate

Closing Transfer Measurement Certificate

Unloading certificate – which summarises the data from the opening and closing transfer certificates

2.5. TLNG Measurement Tests and Methods: Determination of the LNG Composition

For LNG Custody Transfer purposes, the quantity of energy transferred from the LNG Carrier to the Terminal is measured in accordance with the methods described in the GIILNG LNG Custody Transfer Handbook.

2.5.1. General

The Operating Company must sample and analyse the Unloaded LNG in accordance with this Section 1.4. In order to determine the either continuous sampling with subsequent analysis as per Section 2.4.2 or on-line sampling and analysis as per Section 2.4.4 may be used. The Operating Company shall decide which system shall be used to determine the official composition of the Unloaded LNG.

The LNG sampling/analysis systems must comply with ISO 8943 for continuous and on-line intermittent analysis systems and with UNI EN ISO 10715 "*Italian Natural Gas Standard – Sampling Guidelines*." A representative of the User may be present at the calibration of the devices and the sampling/analyses procedures, but the absence of a representative will not prevent such activities from taking place.

2.5.2. LNG Sampling System

a) The LNG sampling system shall be located in a weather-tight container on the Terminal in a suitable position on each Terminal main discharge line and must be configured in such a way as to ensure that representative continuous samples are taken from the LNG transfer lines during the period of full rate discharge. The system consists of two (2) LNG sampling systems with integrated vaporisers, equipped with stabiliser and control to ensure control of the phase change from LNG to gas. The LNG is sent from both sampling points to a single automated sampling system so that the cylinders may be filled.

b) The sampled gas is delivered to an online gas chromatograph and used for online analysis. Alternatively, backup samples are taken on a continuous basis and stored in CP/FP containers. This sampling must be performed at a constant rate starting one hour after continuous Unloading at full rate has commenced and must end about one hour prior to the suspension of continuous full rate Unloading.
c) The sampling device shall be sufficient to ensure that (representative) samples are taken from the LNG transfer line at all times during Unloading. It is also designed to extract, transport and process representative LNG samples, which are placed in three (3) 500 cc. stainless steel sample cylinders and sent to the analysers in the conditions required to ensure the proper performance of the analyses in terms of accuracy, repeatability, reproducibility and availability
d) Once the discharge is completed, in the case of the use of the sampling system, the collected composite gas sample will be available in three (3) stainless steel sample cylinders. One sample cylinder must be sent for analysis at an independent onshore laboratory which uses methods that conform to industry standards, one sample cylinder must be made available to the User (delivered to the LNG Carrier), and one sample cylinder must be retained by the Operating Company for at least thirty (30) days. In case of dispute concerning the accuracy of the analyses, the Operating Company's sample shall be further retained until they both (the Operating Company and the User) agree that it may be released.

2.5.3. LNG Online Composition Analysis

The online analysis system uses a gas chromatograph to determine the molar fractions of hydrocarbons and nitrogen in accordance with ISO 8943. The analyses are conducted at five-minute intervals.

For each line, the composition is the average of the readings taken from about one hour from the start of continuous Unloading at full rate until about one hour prior to the suspension of full-rate Unloading. The composition of the Unloaded LNG is determined by taking the average of the two lines, when they are both available

The online analysis system is considered to be the primary system, whereas the continuous sampling system is to be considered as an alternative, which should only be used in case of non-availability and/or malfunction of the primary system. At the User's request, to be submitted with appropriate prior notice before unloading commences, the Operating Company will arrange for spot samples to be taken at 25%, 50% and 75% of unloading, and for them to be stored in the same manner as the samples envisaged by section 1.4.2d).

Before unloading commences and once it has been completed, three analyses must be performed on the calibration gas and sample gas to determine whether the repeatability of peak areas is within acceptable limits, based on the average of the results of the three analyses. The gas chromatography analysis must be carried out according to ISO 6974 Part 4 and the LNG density determined in accordance with the latest revision of the Klosek-McKinley method.

The individual composition readings and their averages shall be rounded off to at least 0.001%. If required, the methane concentration must be corrected to give a sum of composition percentages of 100% the rounding off of molar composition values should be consistent with that specified in the method used.

The online gas chromatographs must be calibrated and/or have calibration checks performed within twenty-four (24) hours of commencement of unloading. They are calibrated by using a standard gas mixture certified by an approved supplier, of renowned accuracy and traceability, and with a certificate of analysis that shows its composition and measurement uncertainties. The quality and composition of the gas will conform to the applicable commercial standards. At the request of the User, the User may arrange for the certified gas mixture to be made available in a composition similar to that expected from the Unloaded LNG, if the certified gas compositions available to the Operating Company are not deemed to be adequate. The requested composition must be sent to the Operating Company not less than 8 weeks (56 days) prior to the start of the allocated delivery slot. Any modification/request made after this period will not be considered. The requested composition will be subject to the approval of the supplier of the gas mixtures, in terms of its feasibility. Once confirmation has been received from the supplier, the Operating Company will officially provide the User with the expected date of arrival of the requested mixture. In the event that the mixture is not made available in time for the start of unloading operations or the supplier declares that it is not feasible, the Operating Company will use a certified gas mixture in its possession for the calibration.

The total sulphur content of the Unloaded LNG is determined in accordance with ISO 19739:2004. If the total sulphur content is less than five (5) mg/Sm³, it is not necessary to analyse the sample for hydrogen sulphide.

2.5.4. Analysis System Specifications

a) The online Gas Chromatograph used for the analyses is installed to verify the quality of the LNG transferred at the Delivery Point. The Gas Chromatograph is self-calibrating and provides an accurate analysis, by direct measurement or calculation, of the LNG composition, density, Wobbe Index and the gross calorific value (GCV). The analysis cycle for each of the gas Chromatographs lasts five (5) minutes.
b) The analysers are installed inside adequate housing. The internal temperature is monitored to ensure that ambient conditions are always adequate. In particular, the analysis equipment consists of:

    1. One (1) composition analyser (gas chromatograph) 100% redundant
    2. One (1) sulphur analyser (gas chromatograph) for H2S, mercaptans, and total sulphur
    3. A dew point analyser (hydrocarbon / water)
    4. A density analyser
    5. An oxygen (O2) analyser
    6. The sampling system

c) The gas chromatograph will be used to analyse the composition (C1 to C6+, N2, CO2) and to calculate GCV, WI, Dr, D, and Z where:

    GCV Gross Calorific Value

    WI Wobbe Index

    Dr Relative density

    D dew point

    Z compressibility factor

To check the accuracy of GCV-Dr-Z-CO2-N2, two (2) test gas samples must be used containing all the components to be determined, one with a GCV of between thirty-seven point three (37.3) and thirty-eight point one (38.1) MJ/Sm3 and the other with a GCV between thirty-eight point nine (38.9) and forty point two (40.2) MJ/Sm3. For each test sample, five (5) analyses shall be carried out, discarding the first two (2). The average composition and the relevant chemical-physical parameters must be calculated on the basis of the last three (3) analyses, verifying whether the relative error in respect of the test gas analysis certificate is within the limits specified below. The method applicable to the Gas Chromatograph (GC) will define the applicable level of precision. The recommended method is that of ISO 6974 Part 4.

C1 – C2	0.1 % molar
C3 – N2 – CO2	0.05 % molar
GCV	50 kJ/Sm3
Dr	0.001
Z	0.001

To check the repeatability of the GC in accordance with the table below, at least seven (7) consecutive analyses of a gas sample containing all the relevant components must be carried out, discarding the first two (2) analyses. For this trial, a certified gas mixture or 'working gas' must be used

GCV	0.5 %
Dr	0.5 %
Z	0.1 %
CO2	0.1 %
N2	0.1 %

d) The gas chromatograph for H2S, mercaptans, and total sulphur analysis and calculation must be within the limits specified below:

Repeatability: ± 2% of full scale

Sensitivity: ± 0.5% of full scale

Analysis time: 6 minutes

e) The dew point analyser (water and hydrocarbons) must be within the limits specified below:

Accuracy: ±0.5°C

Repeatability: according to supplier's standards

Measure frequency: 6 cycles/hour recommended (12 maximum)

Resolution: 0.1 °C

Range: -40 / +20°C

f) The density analyser must be within the limits specified below:

Accuracy: +/- 0.1% of reading

Repeatability: +/- 0.02% of reading

Response time: < 60 sec.

g) The oxygen analyser must be within the limits specified below

Accuracy: +/-1% F.S.

Repeatability: +/- 1% of SPAN

Sensitivity: according to supplier's standards

Response time: according to supplier's standards

h) The humidity analyser must be within the limits specified below

Accuracy: ±1°C

Sensitivity: 0.1 ppmV

Resolution: 0.1 °C

2.5.5. Procedure in Case of Analysis System Failure

In the case of a failure/unavailability of the online analysis system before the start of unloading, the sampling system must be used to determine the LNG composition.

In the case of a failure/unavailability of both the continuous sampling system and the online sampling system, or a fault in the analysis system used by the Cargo surveyor after the unloading, the arithmetic average of the analysis results of the five (5) immediately preceding cargoes (or the total cargoes delivered if less than five (5)) of similar composition to that expected for the current cargo from the same loading port, including the cargoes of other Users, shall be deemed to be the composition of the LNG. If the above is not deemed reliable or feasible by the Cargo Surveyor, the weathered composition according to MOLAS model will be used for the determination of LNG quality within five (5) Business Days of the Unloading of the LNG carrier.

In the event that the LNG expected to be Unloaded was loaded at a regasification terminal through a reloading service, the quality of such LNG will be that measured at the Terminal, unless the User (or a Cargo Surveyor appointed by the latter) provides evidence that the regasification terminal in which the loading took place, is designed and equipped in accordance with commercially accepted standards in terms of the positioning of the sampling system in relation to the cargo tanks.

2.5.6. Analysis of the Composition for Vapour Return

Since the Terminal is not equipped with a sampling system for the returned vapour composition, the determined GCV will be 33,935 MJ/m3 in standard conditions as specified, equivalent to a quality comprising ninety percent (90%) methane and ten percent (10%) nitrogen.

2.6. LNG Measuring Tests and Methods: Determination of Transferred Energy

The quantity of energy transferred from every LNG Carrier is calculated by an independent Cargo Surveyor appointed by the interested parties in conformity with the measurement and calculation methods defined in this document. The maximum error for the determination of the energy received is in accordance with the current standards (GIILNG LNG Custody Transfer Handbook – Third Edition 2010).

The quantity of Unloaded LNG must exclude the volume of vapour returning to the LNG Carrier during the unloading of the LNG.

During the transfer operations, the volume of Unloaded LNG is replaced by the Gas returned from the Terminal.

Once the unloading is completed, a small quantity of LNG remains in the LNG Carrier's tanks. The transferred energy, E, corresponds to the difference between the energy transferred as LNG and that associated with the gas [natural gas (NG) + gas used by the LNG Carrier's engines, if applicable (MG)]:

$$\mathbf{E = E_{LNG} - E_{NG} - E_{MG}}$$

These energy components are evaluated by determining the transferred volumes and/or mass and the average volume- and/or mass-based calorific value during the transfer process, i.e.:

For LNG:

$$E_{LNG} = V_{LNG} \times \delta_{LNG} \times H_{LNG}$$

where:

V_{LNG}: volume of LNG measured in the LNG Carrier's tanks;

δ_{LNG}: density of LNG calculated on the basis of the gas chromatography analyses and temperature

H_{LNG}: average mass-based Gross Calorific Value (GCV) of LNG, calculated by gas chromatography analyses.

For natural gas (NG):

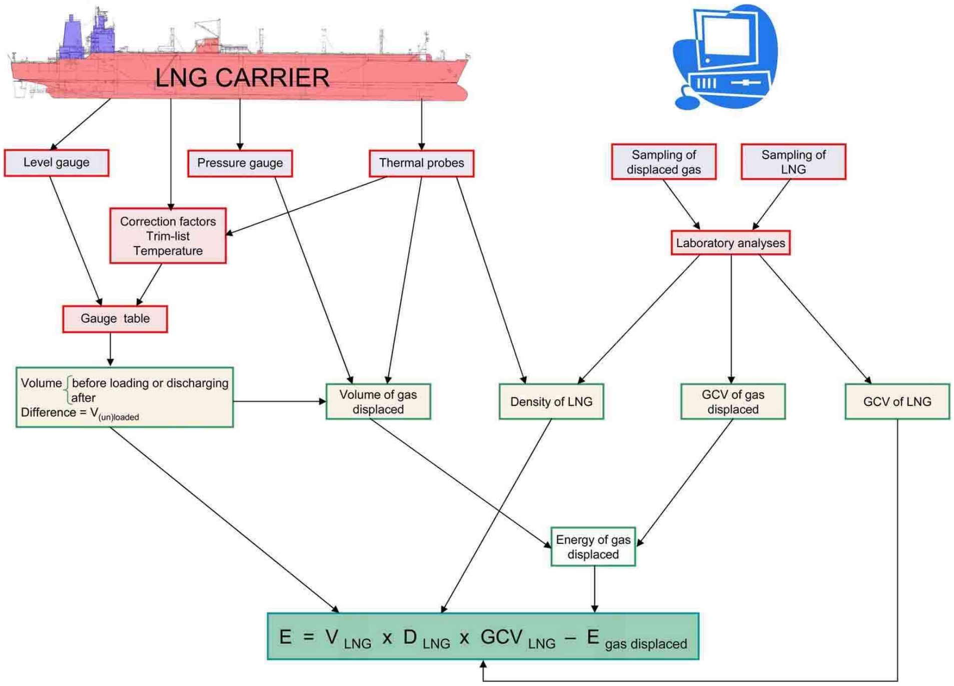
$$E_{NG} = V_{NG} \times H_{NG}$$

where:

V_{NG}: Volume of gas replacing the Unloaded LNG. This volume, brought to standard conditions (288.15 K and 1013.25 mbar) is calculated from the volume of the Unloaded LNG and the temperature and pressure conditions in the tanks at the end of the unloading

H_{NG}: volume-based GCV of vapour

Note: The natural evaporation of the cargo during unloading is not included in the calculation. In fact, the loss of LNG is offset by the lower quantity of Gas returned to the LNG Carrier's.



Cargo inspection principles

2.7. LNG Measuring Tests and Methods: Calculation of Transferred Energy

2.7.1. Calculation of the Gross Energy Discharged

The calculation of the gross energy discharged is a function of:

V_{LNG} : Volume of Unloaded LNG,

δ_{LNG} : density of Unloaded LNG

H_{LNG}: mass-based GCV of Unloaded LNG

$$\mathbf{E_{LNG} = V_{LNG} \times \delta_{LNG} \times H_{LNG}}$$

2.7.2. Calculation of the Volume of Unloaded LNG

Method of Calculation

The volume of Unloaded LNG is calculated as the difference between the volumes of LNG contained in the tanks before and after unloading. The volume of LNG contained in the tank at a given point is determined by a reading from the gauge table, as a function of the level of LNG.

The level of LNG is obtained from the level measured in the tank (average of the level gauges) with the (aforementioned) correction factors applied according to need.

The volume of the LNG Carrier at a given point is the sum of the volumes contained on all the tanks.

2.7.3. Calculation of the Density of the Unloaded LNG δLNG

The density is calculated from various models based on equations of state, corresponding equations of state, etc. with the following input data:

1. The composition of LNG from the gas chromatography analyses after the sampling and vaporisation; the values for molar composition have five decimal places;
2. The temperature of LNG, measured in the LNG Carrier's tanks; the temperature of LNG in measured in °C up to one decimal place (*i.e.*, 0.1).

The calculation to determine the density of LNG uses the latest revision of the Klosek & McKinley method (KMK).

Application Areas for the Calculation Method

The limits of the Klosek & McKinley method for LNG composition and temperature are:

Methane (CH_4)	> 60 % mol.
Iso- and normal butane (iC_4 + nC_4)	< 4 % mol.
Iso- and normal pentane (iC_5 + nC_5)	< 2 % mol.
Nitrogen (N_2)	< 4 % mol.
Temperature (T)	< 115 K < - 158.15 °C

The Klosek Mac Kinley Method Formula

The method for calculating the density of LNG is based on an empirical evaluation of the molar volume of mixtures in a given thermodynamic state. The density is calculated as follows:

$$\rho_{LNG} = \frac{M_{mix}}{V_{mix}}$$

where:

ρ_{LNG}: density of LNG in [$kg \cdot m^{-3}$]

M_{mix}: molecular weight of the mixture in [$kg \cdot kmol^{-1}$]

$$M_{mix} = \sum M_i \cdot X_i$$

where:

M_i : molecular weight of component *i*;

X_i : molar fraction of component *i*.

V_{mix} : molar volume of the mixture expressed in [$l \cdot mol^{-1}$]

$$V_{mix} = \sum X_i \cdot V_i - \left[K_1 + (K_2 - K_1) * \left(\frac{X_{N_2}}{0.0425} \right) \right] * X_{CH_4}$$

where:

X_i : molar fraction of component *i*.

V_i : molar volume of component *i* at the temperature of the LNG

K_1, K_2 : correction factors

The values of K1 and K2, expressed in l/mol, are determined from tables as a function of the molar mass of LNG at temperatures of between 105 K and 135 K. The tables that show molar volumes in [$l \cdot mol^{-1}$] for hydrocarbons from C1 to C5 as a function of temperature varying from 106 K to 118 K are those used for this method. There is no rounding-off when calculating K1, K2 and Vmol.

2.7.4. Calculation of the Mass-Based Calorific Value of the Unloaded LNG - Hm_{LNG}

Method of Calculation

The calculation of the mass-based calorific value of LNG is determined on the basis of the molar composition, the molar mass and the molar calorific value of the various components. The molar mass and the molar calorific value for each component are included in schedule 1 of the tables annexed to this manual:

The correlation is:

$$Hm_{LNG} = \frac{\sum_{i=1}^{N} \left[x_i * H_i^o(t_1) \right]}{\sum_{i=1}^{N} x_i * M}$$

where:

Hm_{LNG} : mass-based calorific value of the mixture [$MJ \cdot kg^{-1}$]

$H^0 i(t_i)$: mass-based calorific value of component *i*, [$MJ \cdot kmol^{-1}$], at a combustion temperature of 15°C

x_i : molar fraction of component *i*

M_i : molar mass of component *i* [$kg \cdot kmol^{-1}$]

2.7.5. Calculation of the Volume-Based GCV of the Unloaded LNG - Hv_{LNG}

Method of Calculation

The calculation of the volume-based GCV (for real gas conditions) of the LNG is determined by the volume-based GCV, the molar composition and by the summation factor of the various components and the molar gas constant. The GCV and the summation factor for each component are include in schedule 1 of the tables.

The correlation is illustrated as follows:

$$Hv_{LNG} = \frac{\sum_{i=1}^{N} \left[x_i * Hv_i \right]}{Z_{mix}}$$

with:

$$Z_{mix} = 1 - \left[\sum_{i=1}^{N} x_i * \sqrt{b_i} \right]^2$$

where:

Hv_{LNG} : Volume-based GCV (real gas conditions) of the mixture [MJ·m3^{-1}]

x_i : molar fraction of component *i*

Hv_i : Volume-based GCV of component *i*, [MJ·m3^{-1}], at the conditions of 15/15°C & 101.325 kPa

Z_i : compression factor at the reference measurement conditions

$\sqrt{b_i}$: summation factor of component *i*, (a 15°C & 101.325 kPa)

2.7.6. Calculation of the Wobbe Index of the Unloaded LNG - WI

The calculation method is based on a real gas, with the following formula:

$$WI = \frac{Hv_{LNG}}{\sqrt{d}}$$

with:

$$d = \sum_{i=1}^{N} \left(x_i * \frac{M_i}{M_{air}} \right) * \frac{Z_{air}}{Z_{mix}}$$

where:

WI: Wobbe Index of the mixture, [MJ·m3^{-1}]

Hv_{LNG} : Volume-based GCV (in real gas conditions) of the mixture

d: relative density of the mixture of real gas

M_i : molar mass of component *i* [kg·kmol^{-1}]

M_{air} : molar mass dry air (28.9626 kg·kmol^{-1})

Z_{mix} : compression factor at the reference measurement conditions

Z_{air} : compression factor in real gas conditions of dry air, at 288.15K & 101.325 kPa (0.99958)

2.7.7. Calculation of the Natural Gas Energy at the LNG Carrier

The calculation of energy returning to the LNG Carrier E_{NG} is based on the following values:

the volume of gas V_{NG}

the Volume-based GCV of natural gas H_{NG}

Since the Terminal does not provide the measure of the Volume-based GCV for returning gas, the value determined will be 33,995 MJ·m^{-3} in standard conditions as specified for real gas conditions, equivalent to a quality of ninety percent (90%) methane and ten percent (10%) nitrogen.

2.7.8. Calculation of the Volume of Natural Gas – VNG

The volume of transferred Natural Gas is calculated as the difference from the volume of LNG transferred on the basis of:

the temperature of the gas phase

the pressure of the gas phase

Between two cargo inspections, natural evaporation is considered together with the volume of transferred LNG, if a corresponding drop in the level of LNG is recorded.

Outside the cargo inspections (before and after), this evaporation is not considered and is, instead, absorbed by the Terminal

Method of calculation

The calculation of the volume of gas returning to the LNG Carrier between two cargo inspections, corresponding to the geometrical volume of the Unloaded LNG, must take place in specific pressure and temperature conditions: 101.325 kPa and 15 °C, respectively. The volume must be corrected based on the temperature and pressure conditions of the gas phase of the LNG Carrier.

Standard conditions (101.325 kPa; 15 °C)

$$V_{NG} \approx V_{LNG} * \frac{288.15}{273.15 + t} * \frac{P}{1013.25}$$

V_{LNG}: Volume of gas in the observed pressure and temperature conditions. There is no rounding-off in the calculation of the volume of returning gas.

P: Observed absolute pressure, expressed in mbar, in the LNG Carrier's tanks. For the calculations, the measurements are rounded off to the nearest mbar.

t: Temperature observed in the vapour phase, in degrees Celsius. The value is equal to the average of the temperatures indicated by the temperature gauges not immerged in the LNG inside the LNG Carrier's tanks. For the calculations, the temperatures precise to one tenth of a degree (0.1 °C)

Measurement Unit and Rounding-Off

The volume of natural gas V_{NG} is expressed in cubic metres [m^3] as specified in standard pressure and temperature conditions (101.325 kPa.; 15 °C), no rounding-off takes place in the natural gas energy calculations.

2.7.9. Calculation of the Net Energy Discharged (formulas and rounding-off for performing the calculation)

Method of calculation

In short, the net discharged energy is expressed according to the formula (standard conditions (1013,25 mbar; 15° C)):

$$E_{LNG} = V_{LNG}\left[\left(\rho_{LNG} * H_{LNG}\right) - \left(\frac{288.15}{273.15+t} * \frac{P}{1013.25} * H_{NG}\right)\right]$$

Measurement unit and rounding-off

All calculations for the net discharged energy are carried out without rounding off and the following input data is used:

V_{LNG}: expressed in [m^3] to the third decimal place

ρ_{LNG}: expressed in kg/m^3 with no rounding off in the calculations; no rounding-off in the calculation of K1, K2 and Vmol; the molar composition of the LNG is rounded off to the fifth decimal place or if it is a molar percentage to the third; the temperature of the LNG in °C is given to the first decimal place

H_{LNG}: Mass-based GCV of the LNG expressed in [MJ·kg^{-1}] with no rounding off in the calculations. The molar composition of the LNG is given to the fifth decimal place or to the third in the case of molar percentages.

t: temperature of the natural gas expressed in [°C] and rounded off to the first decimal place

P: pressure of the natural gas expressed in bar to the third decimal place or in mbar rounded off to the unit

H_{NG}: Volume-based GCV of natural gas expressed in [MJ·m^{-3}] with no rounding off in the calculations. The molar composition of the LNG is rounded off to the fifth decimal place or to the third in the case of molar percentage.

E_{NG}: net discharged energy expressed in GJ without rounding off

Conversions:

MJ to MMBtu (ASTM E380-72) :

1 MMBtu (reference combustion T) = 1055.056 MJ (reference combustion T).

1 kJ·mol^{-1} = 0,00423 MJ·m^{-3}

1 kJ/Sm$^3_{15°/15°}$ = 0.0002775 kWh/ Sm$^3_{25°/15°}$ e 1 kWh/ Sm$^3_{25°/15°}$ = 3603.6 kJ/Sm$^3_{15°/15°}$.

2.8. UNLOADING CERTIFICATE AND REPORT

For unloading certificates and reports, the thermodynamic references are 15° and 1,01325 bara for measurement and 25° and 1,01325 bara for combustion and the energy is expressed in kWh or its multiples, therefore the value shall be converted as below using the following conversion factors:

- *1 kJ/Sm³$_{15°/15°}$ = 0.0002775 kWh/ Sm³$_{25°/15°}$*

  1 kWh/ Sm³$_{25°/15°}$ = 3603.6 kJ/Sm³$_{15°/15}$

the values of the cargo are as follows:

V_{LNG} Before unloading : in [m^3] to the third decimal place

V_{LNG} after unloading : in [m^3] to the third decimal place

$V_{Unloaded\ LNG}$: in [m^3] to the second decimal place

Temperature of the LNG before Unloading: in [°C] to the first decimal place

Tank pressure after Unloading : in [mbar] rounded off to the unit

Temperature of Gas after unloading : in [°C] to the first decimal place

Composition of the LNG : in [mol %] to the third decimal place

Composition of the Natural Gas : in [mol %] to the third decimal place

Wobbe Index : in [kWh·m^{-3} @ 25/15°C & 101.325 kPa] to the second decimal place

Volume-based and mass-based GCV : in [kWh·kg^{-1} @ 25°C] or per [m^3 25/15°C & 101.325 kPa] to the second decimal place

Density of the LNG : in [kg·m^{-3}] to the third decimal place

Density of Gaseous LNG : in [kg·m^{-3}] to the third decimal place

Specific Density of Gaseous LNG : no dimension, to the third decimal place

Quantity of Energy Returning to the LNG Carrier :in [MWh @ 25°C] rounded off to the unit (no digit after the decimal point) and [MMBtu] to the second decimal place

Quantity of Net discharged energy : in [MWh @ 25°C] rounded off to the unit (no digit after the decimal point) and [MMBtu] to the second decimal place

2.9. Specific values of the components of the Natural Gas mixture

HV_i : Volume-based GCV (15/15°C & 101.325 kPa) of component *i*

HM_i: molar GCV (15°C) of component *i*

M_i: molar mass of component *i*

$\sqrt{b_i}$: summation factor (15°C & 101.325 kPa) of component *i*

COMPONENT	PROPERTIES			
	HV_i [MJ/m³]	HM_i [kJ/mol]	M_i [kg/kmol]	$\sqrt{b_i}$
Methane (CH4)	37.706	891.56	16.043	0.0447
Ethane (C2H6)	66.07	1,562.14	30.070	0.0922
Propane (C3H8)	93.94	2,221.10	44.097	0.1338
n-Butane (nC_4H_{10})	121.79	2,879.76	58.123	0.1871
Iso-Butene (iC_4H_{10})	121.40	2,870.58	58.123	0.1789
n-Pentane (nC_5H_{12})	149.66	3,538.60	72.150	0.2510
Iso-Pentane (nC_5H_{12})	149.36	3,531.68	72.150	0.2280
Nitrogen (N_2)	-		28.0135	0.0173
Carbon Dioxide (CO2)	-		44.010	0.0748

Ref.: ISO 6976:1995

2.10. Molar Volumes of the components

COMPONENT	MOLAR VOLUME, l/mol						
	118 K	**116 K**	**114 K**	**112 K**	**110 K**	**108 K**	**106 K**
CH_4	0.038817	0.038536	0.038262	0.037995	0.037735	0.037481	0.037234
C_2H_6	0.048356	0.048184	0.048014	0.047845	0.047678	0.047512	0.047348
C_3H_8	0.062939	0.062756	0.062574	0.062392	0.062212	0.062033	0.061855
iC_4H_{10}	0.078844	0.078640	0.078438	0.078236	0.078035	0.077836	0.077637
nC_4H_{10}	0.077344	0.077150	0.076957	0.076765	0.076574	0.076384	0.076194
iC_5H_{12}	0.092251	0.092032	0.091814	0.091596	0.091379	0.091163	0.090948
nC_5H_{12}	0.092095	0.091884	0.091673	0.091462	0.091252	0.091042	0.090833
N_2	0.050885	0.049179	0.047602	0.046231	0.045031	0.043963	0.043002

Ref. : N.B.S. - Technical note 1030 December 1980.

Volume correction factor - k1 x 10-3

Molecular weight of the mixture	VOLUME REDUCTION, l/mol						
	105 K	**110 K**	**115 K**	**120 K**	**125 K**	**130 K**	**135 K**
16	-0.007	-0.008	-0.009	-0.010	-0.013	-0.015	-0.017
17	0.165	0.180	0.220	0.250	0.295	0.345	0.400
18	0.340	0.375	0.440	0.500	0.590	0.700	0.825
19	0.475	0.535	0.610	0.695	0.795	0.920	1.060
20	0.635	0.725	0.810	0.920	1.035	1.200	1.390
21	0.735	0.835	0.945	1.055	1.210	1.370	1.590
22	0.840	0.950	1.065	1.205	1.385	1.555	1.800
23	0.920	1.055	1.180	1.330	1.525	1.715	1.950
24	1.045	1.155	1.280	1.450	1.640	1.860	2.105
25	1.120	1.245	1.380	1.550	1.750	1.990	2.272

Ref. : N.B.S. - Technical note 1030 December 1980.

Volume correction factor – k2 x 10-3

Molecular weight of the mixture g/mol	VOLUME REDUCTION, l/mol						
	105 K	**110 K**	**115 K**	**120 K**	**125 K**	**130 K**	**135 K**
16	-0.010	-0.015	-0.024	-0.032	-0.043	-0.058	-0.075
17	0.240	0.320	0.410	0.600	0.710	0.950	1.300
18	0.420	0.590	0.720	0.910	1.130	1.460	2.000
19	0.610	0.770	0.950	1.230	1.480	1.920	2.400
20	0.750	0.920	1.150	1.430	1.730	2.200	2.600
21	0.910	1.070	1.220	1.630	1.980	2.420	3.000
22	1.050	1.220	1.300	1.850	2.230	2.680	3.400
23	1.190	1.370	1.450	2.080	2.480	3.000	3.770
24	1.330	1.520	1.650	2.300	2.750	3.320	3.990
25	1.450	1.710	2.000	2.450	2.900	3.520	4.230

Ref. : N.B.S. - Technical note 1030 December 1980.

3. MEASUREMENTS AND TESTS FOR THE EXPORT OF GAS AT THE REDELIVERY POINT

3.1. Gas delivery

There is a complete measurement system to accurately measure the gas which enters the system after regasification. The measurement system is located at the Terminal, and has been built in accordance with the applicable standards and the requirements laid down by domestic and international legislation and by EU Directive 2004/22/EC / CE on measuring instruments (MID) applicable to the fiscal measurement of Natural Gas. The MID was implemented in Italy by Legislative Decree no. 22 of 2 February 2007.

3.1.1. Volume Measurement

The exported gas is fiscally measured by ultrasonic meters with 100% backup

3.1.2. Quality Measurement

The analyser performs a continuous measurement of the defined components within practicable limits.

Two online gas chromatographs (one operating/the other on standby) are installed on the common export line downstream of the metering, to verify whether the quality of the gas exported to the system conforms entirely to the specifications of the entry point. The system must be self-calibrating and, through direct measurement or calculation, it provides an accurate analysis of the composition of the exported gas, its density, Wobbe Index and GCV. The analysis cycle for each gas chromatograph lasts five (5) minutes.

Manual sampling points allow the composition of the NG (gas) to be verified in a laboratory in case of dispute or the unavailability of the online analyser, in accordance with requirements of the System Operator.

In case of non-availability and/or malfunction of the analyser, the flowmeter will measure the flow (see section 4.0.3 below) based on the latest available “good” data, which may be up to nine (9) Days old (and in any case in accordance with the current operating Manual used by SRG and OLT Offshore). If the analyser is unavailable for longer periods, manual sampling will be used by agreement with the relevant parties.

The gas chromatographs conform to the SGR Grid Code (chapter 11 "Gas Quality").

3.1.3. Flow Computers

Each fiscal measurement stream has dedicated flow computers which communicate with their respective flowmeters via a Fieldbus interface and download the data received from the gas chromatographs and field instruments to provide a continuous calculation of the following values:

Volumetric flow rate;

Volumetric flow totaliser;

Mass flow rate and totaliser

Flow direction;

Total energy;

Calorific value calculation;

Gas composition;

Density (in accordance with ISO 6976);

Compressibility factor;

Process Temperature;

Process pressure.

The flow computer provides calculations for the gas flow at the "reference conditions" (as envisaged by ISO 13443 – pressure 101,325 kPa, temperature 288.15 K). The flow computer uses input from the ultrasonic flowmeter to measure the pressure, temperature and compressibility factor in accordance with ISO 12213.

3.1.4. Overall Accuracy of the Measurement System

Overall uncertainty is in line with ISO 5168.

3.1.5. Fiscal Metering Supervisory System (EMMS)

The 100% redundant EMMS provides gas flow and quality data interface, acquisition, processing, storage and reporting. The EMMS checks and validates the composition data from the analysers.

3.1.6. Use of the Fuel Gas Fiscal Metering System

Any fuel gas used within the Terminal is measured fiscally.

The fiscal metering system consists of 2 parallel measurement lines (2x100%) equipped with measuring systems in line with the fiscal metering requirements envisaged by Italian law.

3.1.7. Calibration

The flow computers are calibrated in accordance with SRG standards.

4. Inventory Balancing

Inventory balancing is carried out when necessary and in accordance with the authorisations and the requirements of the Italian tax authorities.

5. Amendments to the values and technical references of this manual

For objective operational and technical reasons, and as a consequence of normative and regulatory developments, the Operating Company may amend one or more values and technical references contained in this manual or it may introduce new parameters with retroactive effect even with regard to commitments already assumed by the Users.

6. Definitions and referenced standards

6.1. List of acronyms

API : American Petroleum Institute

ASTM : ASTM International - formerly American Society for Testing and Materials

ATG : Automatic tank gauge

ATT	:	Automatic tank thermometer
BOG	:	Boil-off gas
CCT	:	Closing Custody Transfer
COS	:	Carbonyl sulphide
CP/FP	:	Constant Pressure, Floating Piston – *applies to gas sample cylinders*
CTS	:	Custody Transfer System
CTMS	:	Custody Transfer Measurement System
D	:	Dew point
Dr	:	Relative density
EN	:	Euro Norm
ISO	:	International Standards Organization
FAT	:	Factory Acceptance Test – *normally performed on the supplier's premises*
GCV	:	Gross Calorific Value
GPA	:	Gas Producers Association
EMC	:	Electromagnetic compatibility –
GC	:	Gas Chromatograph
GCU	:	Gas combustion unit
GIILNG	:	Groupe International des Importateurs de Gaz Naturel Liquefie
GNG	:	Gaseous natural gas
H2S	:	Hydrogen sulphide
IACS	:	International Association of Classification Societies
IAPH	:	International Association of Ports and Harbours
ICS	:	International Chamber of Shipping
IEC	:	International Electrotechnical Commission
IGC Code	:	International Gas Carrier Code
IMO	:	International Maritime Organisation
ISGOTT	:	International Safety Guide for Oil Tankers and Terminals
ISO	:	International Organization for Standardization
MOLAS	:	Models Of LNG Ageing During Ship Transportation
MPMS	:	Manual of Petroleum Measurement Standards

MSDS	:	Material safety data sheet
N_2	:	Nitrogen
NBS	:	National Bureau of Statistics (US)
NG	:	Natural Gas
OBQ	:	On board quantity
OCT	:	Opening Custody Transfer
GCV	:	Gross Calorific Value
SAT	:	Site Acceptance Test – *performed on board the terminal*
SRG	:	Snam Rete Gas
WI	:	Wobbe Index
Z	:	Compressibility

6.2. List of referenced standards with their full titles

Measurement

ISO 10976 Refrigerated light hydrocarbon fluids – Measurement of cargoes onboard LNG carriers

ISO 5725-1 Accuracy (Trueness and precision) of measurement methods and results - Part 1: General Principles and definitions

ISO 18132-1 Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels -- General requirements for automatic tank gauges -- Part 1: Automatic tank gauges for liquefied natural gas on board marine carriers and floating storage.

ISO 8311 Refrigerated light hydrocarbon fluids – Calibration of membrane tanks and independent prismatic tanks in ships – Physical measurement.

ISO 8943 Refrigerated light hydrocarbon fluids -- Sampling of liquefied natural gas -- Continuous and intermittent methods.

ISO 10715 Natural gas – Sampling guidelines

Analyses

ISO 6326-4 Natural gas -- Determination of sulphur compounds -- Part 4: Gas chromatographic method using a flame photometric detector for the determination of hydrogen sulphide, carbonyl sulphide and sulphur-containing odorants **N.B. – this standard has been revised by ISO 19739** – see below

ISO 19739 Natural gas – Determination of sulphur compounds using gas chromatography

ISO 6974 ISO 6974 comprises 6 parts, parts 1 and 2 being guidelines and measuring-system characteristics and statistics for processing of data, parts 3 to 6 being the test methods.

ISO 6974-1 BS EN ISO 6974-1 Natural gas - Determination of composition with defined uncertainty by gas chromatography. Guidelines for tailored analysis

ISO 6974-2 BS EN ISO 6974-2 Natural gas - Determination of composition with defined uncertainty by gas chromatography. Measuring-system characteristics and statistics for processing of data

ISO 6974-3 BS EN ISO 6974-3 Natural gas. - Determination of composition with defined uncertainty by gas chromatography. Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and hydrocarbons up to C8 using two packed columns

ISO 6974-4 BS EN ISO 6974-4 Natural gas - Determination of composition with defined uncertainty by gas chromatography. Determination of nitrogen, carbon dioxide and C1 to C5 and C6+ hydrocarbons for a laboratory and on-line measuring system using two columns

ISO 6974-5 BS EN ISO 6974-5 Natural gas - Determination of composition with defined uncertainty by gas chromatography. Determination of nitrogen, carbon dioxide and C1 to C5 and C6+ hydrocarbons for a laboratory and on-line process application using three columns

ISO 6974-6 BS EN ISO 6974-6 Natural gas - Determination of composition with defined uncertainty by gas chromatography. Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and C1 to C8 hydrocarbons using three capillary columns.

ISO 10715 Natural gas - Sampling guidelines

UNI EN ISO 10715 Italian Natural Gas Standard – Sampling Guidelines.

GPA 2261 Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography

ASTM D1945 -03 Standard Test Method For Analysis of Natural gas by Gas Chroma